



## ETHNOMATHEMATICS IN PALM SUGAR PRODUCTION: EXPLORING MATHEMATICAL ACTIVITIES OF ARTISANS AND STUDENTS THROUGH OUTING USING METACOGNITIVE QUESTIONS

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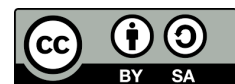
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### ABSTRACT

Palm sugar production represents a cultural practice embedded with mathematical concepts. However, these concepts have not been optimally integrated into formal education, resulting in mathematics often being perceived as abstract and disconnected from real life contexts. This study aims to explore the mathematical activities performed by palm sugar artisans and to describe students' activities in an outing class learning setting employing the problem posing method through a metacognitive questions approach. This research adopted a multi-method design integrating ethnography and phenomenology. Data were collected through observation, interviews, and documentation, and were analyzed using data reduction, data display, and conclusion drawing procedures. The findings identified artisans' mathematical activities, including counting, measuring, designing, locating, and explaining, in accordance with Bishop's framework. Additionally, estimating emerged as a newly identified activity that has the potential to enrich ethnomathematics studies. The implementation of outing class learning through a metacognitive questions approach in the context of palm sugar production demonstrated that students actively engaged in counting, measuring, designing, and explaining activities. These results indicate that this approach has strong potential as a meaningful contextual learning resource for developing students' mathematical activities.

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## 1. INTRODUCTION

Palm sugar is a traditional product with strong historical roots in Indonesian society and has long been produced and consumed as part of local wisdom. It is derived from the sap of the sugar palm tree (*Arenga pinnata*) through a series of processes that continue to preserve traditional techniques grounded in empirical experience (Pranata et al., 2021). Beyond functioning as a food commodity, palm sugar reflects a harmonious relationship between humans and the environment, managed in a sustainable manner. In many rural areas, palm sugar production significantly contributes to strengthening household economies and sustaining family livelihoods (Radam & Rezekiah, 2015). Therefore, palm sugar production can be understood as a socio-economic phenomenon that simultaneously embodies ecological and cultural dimensions.

The production process involves several stages, including sap tapping, filtering, boiling, stirring, molding, and packaging, all carried out systematically based on knowledge transmitted across generations (Hutami et al., 2023). In practice, artisans engage in various rational decision-making processes, such as estimating sap volume, determining boiling duration, maintaining temperature and fire stability, and observing changes in texture and color as indicators of product quality. These activities demonstrate quantitative, relational, and adaptive thinking patterns aligned with principles of formal mathematics and reflect what Bishop (1988) conceptualizes as fundamental mathematical activities embedded in cultural practices, namely counting, measuring, designing, locating, playing, and explaining. Research conducted in Saotengnga Village revealed that the sustainability of this practice is closely connected to embedded cultural and religious values (Rusli & Darmayanti, 2023). This finding highlights that traditional practices represent complex knowledge systems worthy of academic investigation.

The relationship between cultural practices and mathematical activities is a central focus of ethnomathematics. From an ethnomathematical perspective, mathematics is viewed as a social construct that develops within specific cultural contexts, rather than merely a collection of abstract concepts detached from real-life situations. Each cultural community possesses distinctive ways of understanding, representing, and applying mathematical ideas in daily activities (Rosa et al., 2016). Within this framework, activities such as estimating, measuring, comparing, regulating proportions, and structuring procedures in palm sugar production can be interpreted as contextual manifestations of Bishop (1988) six universal mathematical activities. Consequently, exploring local cultural practices is essential for broadening understanding of the existence and function of mathematics in social life.

Several previous studies have identified mathematical activities embedded in various cultural practices in Indonesia. Mathematical activities have been found in rice farming practices involving land area calculations and harvest yield estimations (Chabibah et al., 2025). Other research has revealed ethnomathematical elements in traditional food production, such as geometric shapes, proportional reasoning, repeated patterns, and symmetry observed in the preparation of traditional Javanese foods *getuk* and *kue lapis* (Harahap & Ananda, 2025). Furthermore, traditional food production such as Kue Barongko demonstrates the application of measurement and proportional reasoning (Pathuddin et al., 2021). In addition, cultural rituals also reflect mathematical reasoning, including numerical systems and logical reasoning embedded in the wedding traditions of the Dayak Muntak community (Saputri et al., 2025). Despite these contributions, prior studies predominantly focus on identifying mathematical elements within cultural artifacts without critically examining how mathematical activities emerge through dynamic production processes or how such culturally embedded knowledge can be pedagogically transformed through contextual learning approaches such as outing class; consequently, the integration of palm

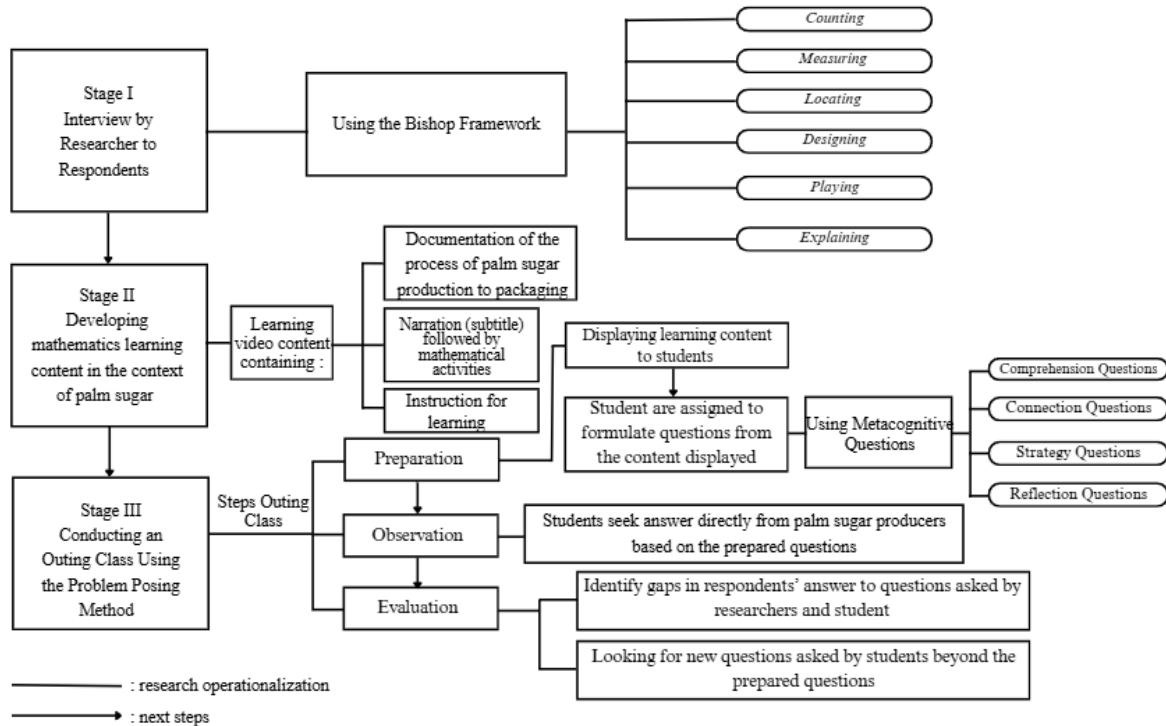
sugar production into meaningful mathematics learning experiences remains insufficiently explored and theoretically underdeveloped.

On the other hand, mathematics education in schools continues to face challenges in bridging abstract concepts with students' concrete experiences. Difficulties in learning mathematics are often influenced by the lack of contextual relevance to students' everyday lives (Setioningsih et al., 2025). When mathematics is presented symbolically without meaningful connections to reality, students tend to perceive it as rigid and less meaningful. Integrating cultural contexts into instruction has the potential to enhance relevance, motivation, and meaningful learning experiences (Payadnya et al., 2024). One instructional approach that supports contextual learning is the outing class, which provides students with opportunities to directly observe real phenomena in their surrounding environment (Suciati, 2023).

To ensure that contextual learning fosters higher-order thinking skills, pedagogical strategies that stimulate cognitive engagement and reflection are required. The problem-posing method allows students to formulate questions and problems based on directly observed phenomena (Baumanns & Rott, 2024). Additionally, the use of metacognitive questions plays an essential role in helping students plan strategies, monitor their thinking processes, and evaluate the solutions they generate (Syahmani et al., 2021). In response to the gap in ethnomathematics research and the need for contextual learning, this study aims to explore the mathematical activities of insiders (palm sugar artisans) in the palm sugar production process and to examine students' mathematical activities in outing class-based learning within the context of palm sugar production through the problem-posing method using a metacognitive questions approach. The novelty of this study lies in the integrated exploration of mathematical activities from both cultural practitioners (artisans) and students within a single ethnomathematical framework, combined with the implementation of outing class learning through problem posing supported by metacognitive questions, which has not been explicitly addressed in previous studies. This study bridges the mathematical reasoning that naturally develops within artisans' practices with students' mathematics learning processes, thereby establishing a conceptual linkage between cultural contexts and the construction of formal knowledge in the classroom. This study is expected to contribute both theoretically and practically to the development of contextual mathematics learning grounded in local wisdom.

## **2. METHOD**

This study employed a multi-method approach, defined as the use of more than one research method according to the focus of the study without integrating the findings in the final stage of analysis (Yulianto, 2023). Ethnography was applied to examine the mathematical activities of palm sugar artisans during the production process, while phenomenology was used to understand students' learning experiences in outing class-based instruction. Data were collected through methodological triangulation, including observation, interviews, and documentation. The researcher functioned as the primary human instrument responsible for determining the research focus, selecting informants, collecting data, and interpreting findings, as proposed by Creswell (Bado, 2021). Supporting instruments included interview guidelines, observation sheets, documentation guidelines, and student worksheets designed based on metacognitive questions. The research procedure is illustrated in figure 1.



**Figure 1. Research Procedure**

Based on figure 1, the study was conducted in three stages. Stage I involved interviews and observations to identify mathematical activities in palm sugar production using Bishop's framework supported by production documentation. Stage II focused on developing contextual mathematics learning content in the form of instructional videos for outing class activities. Stage III implemented outing class-based learning through the problem-posing method supported by metacognitive questions, where students formulated questions, interacted directly with artisans, and participated in evaluation to examine learning responses and emerging inquiries.

Data analysis followed the interactive model of Miles and Huberman, consisting of data reduction, data display, and conclusion drawing and verification. Data reduction was conducted through transcription, selection, and coding based on relevant categories of mathematical activities, while data presentation was organized in a descriptive narrative form. Data trustworthiness was ensured through the criteria of credibility, transferability, dependability, and confirmability (Lincoln & Guba, 1985). The study was conducted in Cikubang Hamlet, Cukangjayaguna Village, Sodonghilir District, Tasikmalaya Regency. The research participants consisted of seven palm sugar artisans directly involved in production and eight students from SMA Negeri 1 Taraju selected through convenience sampling based on specific criteria, including active involvement in palm sugar production for artisans and students' participation in outing class learning activities as well as their willingness to engage in interviews and observations.

### 3. RESULTS AND DISCUSSION

#### 3.1. Results

This study identified mathematical activities embedded in palm sugar production based on Bishop's six categories: counting, measuring, designing, locating, playing, and explaining. The findings revealed the explicit emergence of five activities, namely counting,

measuring, designing, locating, and explaining, as well as one additional activity, namely estimating. These results confirm that palm sugar production embodies contextual and complex mathematical practices. During the stages of tapping, cooking, molding, and packaging, artisans implicitly applied concepts of arithmetic, measurement, comparison, geometry, and spatial reasoning grounded in empirical experience. The following are the mathematical activities found in palm sugar production.

**Table 1.** Mathematical Activities in Palm Sugar Production

Type of Mathematical Activity	Artisan Activities
Counting	<ol style="list-style-type: none"> <li>1. Counting the number of swings when hitting the male flower clusters</li> <li>2. Counting the number of times the bunch is struck and swung</li> <li>3. Counting the frequency of tapping</li> <li>4. Counting the number of pieces of palm sugar in one package</li> <li>5. Counting the selling price per kilogram or per package</li> </ol>
Measuring	<ol style="list-style-type: none"> <li>1. Measuring the length of time male flower clusters can be tapped</li> <li>2. Measuring the volume of the palm sap container</li> <li>3. Measuring the cooking time of palm sap</li> <li>4. Measuring the palm sugar mold</li> <li>5. Measuring the weight of sugar</li> </ol>
Designing	Found in tools used in the palm sugar production process
Locating	<ol style="list-style-type: none"> <li>1. Positioning the container (<i>lodong</i>)</li> <li>2. Positioning the bamboo footrest (<i>sigai</i>) with the palm tree</li> </ol>
Playing	Not found
Explaining	Palm sugar craftsmen can explain the entire production process
Estimating (not covered in the bishop framework)	<ol style="list-style-type: none"> <li>1. Estimating the difference in yield between morning and afternoon tapping</li> <li>2. Estimating palm sugar yield based on the amount of sap boiled</li> </ol>

Counting activities emerged during tapping, packaging, and price determination. In the tapping stage, artisans counted the number of swings applied to the male flower cluster before sap extraction began. The number ranged from 50 – 70 swings for medium-sized clusters and 70 – 100 swings for larger clusters. This practice reflects a direct proportional relationship between the physical size of the cluster and the required number of swings. Mathematically, the minimum ratio between medium and large clusters is approximately  $50:70 \approx 0.71$ , while the maximum ratio is  $70:100 = 0.70$ , indicating proportional reasoning.

Counting was also observed in the scheduling of tapping preparation, performed three times per week over four weeks before the tree was ready for tapping. This pattern reflects an arithmetic sequence with a common difference of seven days and demonstrates understanding of time unit conversion (four weeks = 28 days). Additionally, tapping frequency was calculated twice daily (morning and afternoon). Observational data indicated that afternoon sap yields were consistently higher than morning yields, with empirical ratios

ranging from 1,18 to 1,30. This reflects an implicit understanding of proportional comparison between time intervals and sap volume.





Counting further appeared in packaging, where each package contained 10 palm sugar pieces counted manually. This practice illustrates one-to-one correspondence, division (e.g., 60 pieces  $\div$  10 = 6 packages), and fraction concepts (1 piece =  $\frac{1}{10}$  of a package). Artisans also calculated selling prices per package and per kilogram. Analysis showed that the equivalent price per kilogram from packaged products (approximately IDR 15,600 – 15,800/kg) was lower than the direct selling price to collectors (IDR 17,000/kg), indicating comparative numerical reasoning.


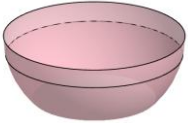









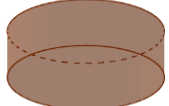
Measuring activities were identified in determining tapping duration, container volume, cooking time, mold dimensions, and sugar weight. A single flower cluster could be tapped for 2 – 4 months, and up to 7 – 12 months for fertile trees, reflecting interval and duration comparisons. The measurement of the bamboo container (*lodong*) demonstrates spatial geometric reasoning, particularly the volume of a cylinder ( $V = \pi r^2 h$ ). Afternoon containers had larger capacities, anticipating greater sap volume. Cooking duration showed a direct proportional relationship with sap volume: artisans processing 8.7 and 10.4 liters required 7 hours and 41 minutes, whereas smaller volumes required approximately five hours.

In the molding stage, cylindrical molds measured 9 – 9,8 cm in diameter and 1,4 – 1,7 cm in height, producing volumes between approximately 89 – 128 cm<sup>3</sup>. This demonstrates application of circular area and cylinder volume concepts affecting the mass of the final product.

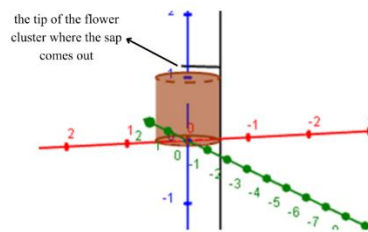
Designing was reflected in the shapes of production tools incorporating plane and solid geometric forms. Equipment such as the paninggur, tapping knife, *lodong*, filter, frying pan, guguis, spoon handle, molds, and ebeg embody geometric structures including cylinders, blocks, truncated cones, hemispheres, squares, and rectangles. These tools illustrate how geometric principles are embedded in functional design grounded in practical needs.

**Table 2.** Designing Palm Sugar Production Equipment

Object	Object Analysis	Object	Object Analysis
	Geometric Shape: Cylinder		Geometric Shape: Cylinder and Block
	Geometric Shape: Cylinder		Geometric Shape: Truncated Cone

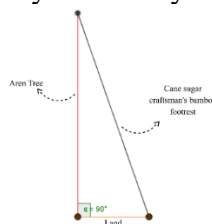
<p>Frying pan</p> 	<p>Geometric Shape: Hemisphere</p> 	<p>Guguis</p> 	<p>Geometric Shape: Cylinder</p> 
<p>Spoon</p> 	<p>Geometric Shape (Handle): Cylinder</p> 	<p>Mold</p> 	<p>Geometric Shape: Cylinder</p> 
<p>Ebeg</p> 	<p>Geometric Shape: Square/Rectangle</p> 	<p>Palm Sugar</p> 	<p>Geometric Shapes: Cylinder</p> 

Locating emerged when artisans positioned the lodong so that sap fell precisely into the container. Mathematically, this situation can be modeled using a three dimensional coordinate system considering horizontal distance and height differences between the flower cluster and the container opening. Proper placement requires that the projection of the falling point lies within the radius of the cylindrical opening and satisfies height relations.



**Figure 2.** Visualization of *Lodong* and Flower Cluster Placement

Similarly, positioning the bamboo ladder (*sigai*) forms a triangular configuration between the ground, tree trunk, and bamboo support. Determining the inclination angle reflects spatial reasoning related to stability and safety.



**Figure 3.** Visualization of *Sigai* Position with Palm Trees and Soil

Explaining was evident in artisans' ability to describe sequential production stages, tool functions, and causal relationships within the process. Their explanations contained elements of classification, logical argumentation, and systematic narrative structure, indicating that production practices are not merely procedural but also conceptual and reflective.

An additional finding was the emergence of estimating, which is not included in Bishop's six categories. Artisans estimated differences between morning and afternoon yields using approximate ratios such as 4: 3 or 3: 2,5. Comparisons between estimated and actual ratios (e. g., 1,2 vs. 1,18; 1,33 vs. 1,19) showed close correspondence, suggesting high quantitative accuracy derived from repeated experience rather than formal calculation. Estimation also appeared in predicting sugar output per cooking session. The expression "one package or more" referred to approximately 10 pieces, while actual results ranged from 7 – 14 pieces, indicating developed numerical intuition through sustained practice. Based on the identified artisan activities, contextual learning content was developed and integrated into an outing class program. Instructional materials were presented in video format, incorporating narration of mathematical activities, analytical subtitles emphasizing concepts, and problem-posing instructions. After viewing the video, students formulated questions independently using metacognitive questions categorized as comprehension, connection, strategy, and reflection. The distribution of the types of questions asked by students is presented in the following table.

**Table. 3.** Questions and Categories of Metacognitive Questions

Students	Questions	Metacognitive Questions Categories
Student 1	1. What is the size of the container for collecting sap?	Comprehension Questions
	2. How much does palm sugar cost?	Comprehension Questions
	3. How much does the molded palm sugar weigh?	Comprehension Questions
Student 2	1. What is the size of the pan used?	Comprehension Questions
	2. How much does 1 piece of palm sugar weigh?	Comprehension Questions
	3. What size <i>ebeg</i> was used when making palm sugar?	Comprehension Questions
Student 3	1. What is the size of the container used for tapping?	Comprehension Questions
	2. How much palm sap is collected in one day?	Comprehension Questions
	3. How long does it take to cook sap?	Comprehension Questions
	4. What size pan is used?	Comprehension Questions
	5. What size mold is used?	Comprehension Questions
	6. What was the price of palm sugar when it was sold?	Comprehension Questions
	7. How much does a package of sugar weigh?	Comprehension Questions
Student 4	1. How much sap is produced from tapping?	Comprehension Questions
	2. How long does it take to boil palm sap?	Comprehension Questions
	3. How can you ensure that all the sugar cubes are the same size?	Strategy Questions

Students	Questions	Metacognitive Questions Categories
Student 5	1. What is the difference between the sap produced in the morning and in the afternoon?	Connection Questions
	2. Is the sap yield the same every day?	Reflection Questions
	3. How many sugar cubes are there in 1 kg of sugar?	Comprehension Questions
Student 6	1. How much sap does one tree produce?	Comprehension Questions
	2. What is the size of palm sugar?	Comprehension Questions
	3. What is the size of the palm sugar mold?	Comprehension Questions
	4. How much wood is used in cooking palm sap?	Comprehension Questions
Student 7	1. How much wood is used in cooking palm sap?	Comprehension Questions
	2. How much wood is used in boiling palm sugar?	Comprehension Questions
	3. What is the size of the sugar mold?	Comprehension Questions
	4. What is the size of the <i>ebeg</i> ?	Comprehension Questions
	5. What is the selling price of palm sugar?	Comprehension Questions
Student 8	1. What is the size of the bamboo used to collect palm sap?	Comprehension Questions
	2. How long can palm sap boil?	Comprehension Questions
	3. The morning and afternoon harvests are different. How are they different?	Connection Questions
	4. What size mold is used?	Comprehension Questions

Analysis revealed that comprehension questions predominated, particularly regarding tool dimensions, sap volume, sugar weight, selling price, and cooking duration. Connection, strategy, and reflection questions were limited, indicating that students were primarily operating at the factual understanding level. Nevertheless, spontaneous additional questions emerged during field observation, reflecting authentic cognitive engagement. The additional questions that arose are as follows.

**Table 4.** Additional Questions

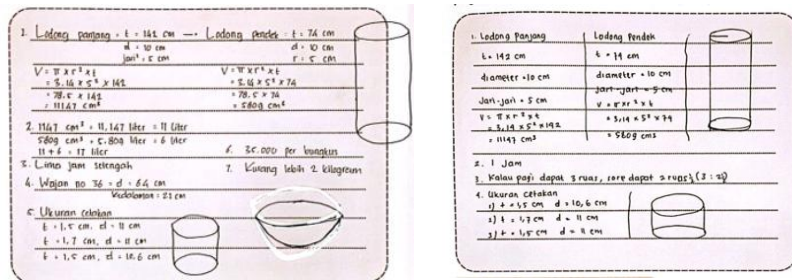
Students	Questions
Student 3	Is the cooking time for palm sap the same every day?
Student 6	1. How much sugar is used in each mold?
	2. Has the selling price of palm sugar ever decreased?
Student 7	1. What types of wood are used?
	2. How long does it take for the molded sugar to cool and be packaged?

During the outing class, students demonstrated mathematical activities in counting, measuring, designing, and explaining, while locating and playing were not identified.

**Table 5.** Students Mathematical Activities

Type of Mathematical Activity	Student Activities
Counting	1. Calculating the volume of the palm sap container 2. Calculating the area and perimeter of the <i>ebeg</i> 3. Calculating the yield of sap tapping in one day 4. Calculating the cooking time for palm sap 5. Calculating the weight of 1 piece of sugar from the weight of one package of palm sugar 6. Calculating the volume of a mold
Measuring	1. Measuring the size of the palm sap container 2. Measuring the sides of the mold 3. Measuring the palm sugar mold 4. Measuring the weight of palm sugar
Designing	Students visualize several objects related to palm sugar production
Locating	Not found
Playing	Not found
Explaining	Students conclude

Counting activities included calculating container volume, determining the area and perimeter of the *ebeg*, estimating daily sap yield (approximately 17 liters), calculating cooking duration (5 hours 30 minutes), determining the weight of one sugar piece (200 grams), and computing mold volumes ( $142.48 \text{ cm}^3$  and  $117.75 \text{ cm}^3$ ). These results indicate engagement in arithmetic operations, geometric reasoning, and unit conversions grounded in real contexts. The following is a picture of some of the students' calculations in the outing class.

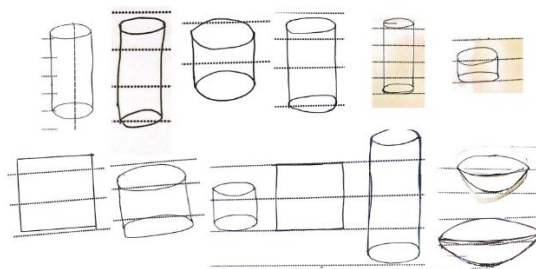

**Figure 4.** Students Calculation Results

Measuring activities involved determining container dimensions, *ebeg* sides, mold sizes, and sugar weight, reflecting application of length, area, volume, and mass measurement concepts. The following are pictures of the students' measuring activities.



**Figure 5.** Student Assessment Activities

Designing emerged when students visualized and sketched production tools, demonstrating spatial representation skills. Below are pictures of the sketches made by the students.



**Figure 6.** Sketches of Tools Drawn by Students

Explaining was observed in students' ability to formulate conclusions based on observation and calculation.

### 3.2. Discussion

Overall, the findings of this study indicate that outing class-based learning implemented through the problem posing method with a metacognitive questions approach effectively facilitates the emergence of contextual and meaningful mathematical activities. Although students' questions were still predominantly at the level of comprehension, the presence of connection, strategy, and reflection questions suggests the development of early metacognitive awareness. The integration of the palm sugar production context into classroom instruction strengthened the linkage between students' empirical experiences and the construction of formal mathematical concepts, thereby supporting the simultaneous development of mathematical and metacognitive abilities. These findings are consistent with the study by Yumiati et al. (2023), which demonstrated that ethnomathematics-based learning in an outing class setting can enhance the quality of mathematics learning outcomes. Similar results were also reported by Prasetyo et al. (2025), who found that integrating ethnomathematical contexts into learning contributes to positive changes in students' perceptions of mathematics and stimulates cognitive development toward higher-order thinking skills.

The analysis of mathematical activities reveals both continuity and epistemic shifts between artisans' practices and students' academic constructions. In the counting activity, artisans perform contextual and adaptive calculations to support production decisions, aligning with the view that counting practices within cultural contexts develop from practical needs (Rosa et al., 2016). In contrast, students transform these practices into formal

quantification through formulas, arithmetic operations, and unit conversions as a form of progressive mathematization. In the measuring activity, artisans employ contextual units and experience-based estimations. Meanwhile, students use standardized measuring instruments and mathematical analysis, resulting in a more verificative and analytical form of measurement. These findings extend the work of Mulyadi (2020) and Apendi & Ginting (2023), who identified measurement and geometric concepts in culture-based production practices, by emphasizing the transformation from operational practice to formal representation in the classroom.

In the designing activity, artisans construct production tools based on functional efficiency and empirical experience, reflecting the development of cultural geometry arising from practical needs, as noted by Gerdes (Mosimege, 2012). Students subsequently reconstruct these forms into formal geometric representations. This result enriches the findings of Pathuddin et al. (2021) and Harahap & Ananda (2025), which emphasized the identification of geometric and proportional concepts embedded in traditional food production practices, by demonstrating a more systematic process of mathematical modeling in classroom settings. In the explaining activity, artisans' experience-based procedural narratives are transformed into data-based mathematical arguments constructed by students. This transformation reflects a shift from implicit to explicit knowledge, as described by Cimen (2014), and highlights the role of metacognitive questions in structuring students' explanations more systematically.

Conversely, the locating and estimating activities were identified only among artisans, as they are closely related to spatial and predictive needs within practical domains (Rosa et al., 2016). The absence of these activities among students indicates a difference in epistemic positioning rather than a conceptual deficiency. The playing activity was also not observed, as palm sugar production is a procedural work practice rather than an exploratory one. Overall, the mathematical activities of artisans and students lie along the same spectrum but differ in their level of formalization. Artisans represent mathematics as contextual and adaptive practice, whereas students represent it as a systematic and measurable symbolic structure. The integration of both perspectives within outing class learning affirms that ethnomathematics extends beyond merely identifying mathematical concepts in culture; it constitutes an epistemological transformation process from cultural practice to the construction of formal mathematics relevant to contextual learning (Sutarto et al., 2021). This perspective is also supported by Saputri et al. (2025), who demonstrated that mathematical reasoning embedded in cultural rituals reflects structured logical thinking that can be reconstructed into formal academic knowledge.

From a metacognitive perspective, the dominance of comprehension and connection questions indicates that students are at an emerging stage of metacognitive awareness, where they begin to monitor understanding and relate contextual experiences to prior mathematical knowledge (Kramarski & Zoldan, 2008), reflects the initial development of metacognitive regulation; however, the limited presence of strategy and reflection questions suggests that higher-order planning and evaluative skills have not yet been optimally formed, supporting Syahmani et al. (2021) assertion that advanced metacognitive competencies require sustained scaffolding and structured instructional support within the learning process.

#### 4. CONCLUSION

This study demonstrates that the process of palm sugar production embodies a variety of mathematical activities naturally performed by artisans, including counting, measuring, designing, locating, and explaining at each stage of production. In addition, an estimating activity was identified, which is not explicitly included in Bishop's classification, yet plays

a significant role in predicting sap yield and the quantity of sugar produced. This finding enriches ethnomathematics research by showing that cultural practices may reveal forms of mathematical activity not fully accommodated within existing theoretical frameworks. In the context of learning, the implementation of an outing class combined with the problem-posing method and a metacognitive questions approach encouraged the emergence of students' mathematical activities through direct interaction with real world contexts. Although most students' questions were initially at a basic comprehension level, the progression toward connection, strategy, and reflection questions indicates potential metacognitive growth. The students' engagement in counting, measuring, designing, and explaining further confirms that culturally contextualized learning supports a more concrete and meaningful understanding of mathematical concepts.

The identification of estimating as an additional activity opens opportunities to develop a more comprehensive framework of mathematical activities through investigations in other cultural contexts and through approaches such as grounded theory. Overall, integrating local cultural contexts through outing class activities and a metacognitive approach fosters more participatory and reflective mathematics learning, while promoting deeper conceptual understanding. Nevertheless, this study has several limitations. The findings are context-specific, as the exploration of mathematical activities was conducted within a particular cultural and geographical setting. The identification of estimating remains exploratory since a grounded theory approach was not employed to develop new theoretical categories. In addition, the limited duration of implementation and number of student participants restricted the analysis to emerging learning activities rather than long-term learning outcomes or sustained metacognitive development.

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